RESEARCH DEPARTMENT

U.H.F. service area prediction:
an investigation using relief map photography

RESEARCH REPORT No. K-181
UDC 621.391.812.8. 029.63: 77 1966/45

THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

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August 1966

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SUMMARY

An experiment was undertaken to determine whether the service areas of u.h.f. broadcasting transmitters could be reliably predicted by photographing a three-dimensional relief map suitably illuminated. The results obtained are discussed.

1. INTRODUCTION

Workers interested in forecasting the service areas of broadcasting transmitters have attempted from time to time to predict the extent of a proposed service by photographing an illuminated relief map. The most recent work in this field was done in Germany,[1,2] but neither these nor earlier experiments were directed to establishing a metrical relationship between the densities recorded in the photograph and the field strengths to be expected in the area. The best that was achieved was a good qualitative representation of the proposed service.

In order to determine whether the photographic method could be carried successfully beyond the qualitative stage, an experiment was undertaken with the following ideal objectives in mind:

1. The image density at all points in the photograph should represent accurately, and be interpretable as, the field strength which the proposed transmitter will provide at the same points in the real service area.

2. The procedure developed should be capable of routine application and should not demand of the operator a knowledge of radiowave propagation.

A great saving in effort would of course be realized if these objectives could be attained absolutely, and this consideration provided a strong incentive to develop a method that would be acceptably accurate.

In this experiment, predictions of the service areas of seventeen of the transmitting stations proposed for the u.h.f. television services in the U.K. were made. Six of these areas have since been measured in site tests, the results providing a reference against which the predictions may be compared. Such comparisons were made, and are discussed later. Although they indicate that the probability of agreement between prediction and measurement is not sufficiently high to establish the method as a rival to measurement, they show that, even at the state of development so far reached, the method is capable of giving a good preliminary indication of the extent of a service area, and indeed, a better indication than any which the usual empirical procedures of estimating provide. The source of greatest error lay in the limits imposed by the experimental conditions. A lamp of small dimensions was necessary and the intensity of the light source was consequently limited. The map used had a white surface in order that the best use could be made of the available light. The high reflectivity of the map however produced a large amount of unwanted scatter which falsified the shadows. These errors were edited out of the final result by inspection, introducing, however, errors of interpretation. It may be expected that by lowering the reflectivity of the map to a level where scatter may be neglected, the original aim of developing an entirely objective method of prediction would be met, and error reduced.

2. ARRANGEMENT OF THE EXPERIMENT

The three dimensional map used for the photographs was constructed on a spherical base of 9 ft (2·74 m) radius. The horizontal scale was 1 in. = 4 miles (1 cm = 2·5 km), the vertical scale being exaggerated by a factor of twelve. The land areas were white, and the sea blue.

The centre wavelength of visible light ($\lambda = 0{\cdot}55 \times 10^{-6}$ m) is relatively 2 to 4 times shorter than that of the u.h.f. bands when corrected by the horizontal scale ratio of the map ($1 : 0{\cdot}25 \times 10^{6}$). Light

would therefore be diffracted through a smaller angle on the model than u.h.f. radio waves in the real case, even if the vertical scale of the map had been the same as the horizontal. With the relief exaggerated vertically, the shadows in the map are so deep as to be, for practical purposes, completely black.

In the German paper[2] already mentioned, the suggestion is made that the finite levels of field strength in the radio shadows may be simulated in the model by taking several photographs of the map on the same negative, placing the lamp at different heights above the surface. The method of prediction which is the subject of this report consisted in evolving a way of determining the lamp heights and exposure times which would be uniquely representative of propagation conditions in a given area and be therefore capable of providing a photograph in which the relative densities were the same as the relative field strengths in the real case.

The curves[3] published by the CCIR were taken as the starting point in establishing the propagation conditions to be simulated in the photographs. These express the propagation law for median (location) field strengths over the rolling irregular terrain found in many parts of Europe. They may be regarded as curves for propagation over a smoothed version of such terrain.

The aim when determining the lamp heights and exposure times was to produce an analogue of propagation conditions over smooth terrain, whether in front of or behind isolated obstacles (which are not considered in the CCIR curves[3]) and to rely on the relief of the map to produce the variations due to ground irregularities. The particular CCIR curve chosen in each case was that related to the height of the transmitting aerial. The terrain in the service area was sampled by selecting radials centred on the transmitter, each radial containing a prominent obstacle. These obstacles were treated as isolated diffracting half-planes and the diffraction loss behind them calculated and, over the appropriate distance range, subtracted from the basic CCIR curve. The resulting curves formed a family which was simulated by varying the height of the lamp and the length of the associated photographic exposure. The effects of all the lamp positions were summed by taking all the photographs on a single negative. It is not, however, proposed to describe here the steps by which the parameters for taking the photographs were derived.

The lay-out of the experiment is depicted in Fig. 1, where the map is shown standing on the floor and the camera fixed to a cross-beam about 6 ft (1·8 m) above it. Calibration of the photographic densities in field strength was achieved by photographing a "calibration standard" (Fig. 2) in the same way, the standard consisting of a cylindrical section of 9 ft (2·74 m) radius, with a decibel scale affixed to it. The photograph of this standard was taken with the lamp at a standard height above the surface and with a standardized exposure. The resulting photograph appeared as a continuously graded range of density related to the decibel scale.

A separate photograph of the calibration standard was taken with each prediction photograph, and the two negatives were processed simultaneously in the same baths. It was then assumed that areas of equal density in the two photographs signified that the product of light intensity and exposure time was the same for the two areas. The densities in the photograph of the calibration standard were related to field strength on the CCIR curve, and by applying the ratio between the exposures given to the photographs of the map and the standard, the field strength values were extrapolated to the densities in the prediction photograph.

It was not possible in practice (for reasons depending on physical laws) to arrange that a single extrapolation ratio applied to all densities in the prediction photograph. The ratios used in all the predictions of this experiment were those applicable to field strengths on the CCIR curve at distances between 30 and 35 miles (48 and 56 km) from the transmitter. The service limit for the e.r.p.'s of the transmitters considered was assumed to lie in this range of distance, and in choosing a value in this range, the greatest accuracy was obtained at the limit of the service. It should be mentioned in passing that because of the long exposure times required with the lamp in some positions, the relationship between light intensity and exposure time was non-linear in this experiment, and a correction had to be applied for this effect.

A further correction was also necessary. It is a matter of experience that the medians of field strength measurements in towns are always lower than the field strengths indicated on the CCIR median curves. The difference is referred to as the urban depression of the median and treated as a constant ratio. To determine the urban depression factor applicable to these predictions, a prediction photograph of the Crystal Palace service area was made and the predicted contours compared with measured results, of which a large number were available. The factor derived in this way was applied to all predictions, and it may therefore be said that, although based on the CCIR curve, the method evolved was used as a vehicle for transferring the results of measurement in the Crystal Palace area to other areas.

3. COMPARISON OF PREDICTION WITH MEASUREMENT

The predicted limit-of-service contours for six sites, depicted in Figs. 3 to 8 by solid lines, are compared with the service boundaries established by measurement, drawn as broken lines. The two lines are different in character and coincidence between them cannot be expected. The predicted line purports to be a contour whose value is the limiting field strength, whereas the line representing the measured service is a boundary which treats as served, the towns where over 70% of the area receives a field strength greater than the limiting value, and villages where the area served is greater than 50%. The places shown in the figures indicate where the measurements were carried out. It will be seen that these lie mainly in the outer parts of the service areas.

Because a comparison of the contours is not strictly valid, statistical comparisons were also made. A large part of the errors that emerged from these analyses were found to result from visual editing of the photographs. It has already been mentioned that, due to the high level of reflexions from the white surface of the map, visual editing became necessary; this type of error can be virtually removed from the system by painting the map grey and reducing its reflexion coefficient to a low value, but this has not been tried.

For the first statistical comparison, the towns where measurements had been carried out were listed as served or unserved, separately in respect of the site tests and the predictions. They were then divided into two catagories, one where the predictions agreed with the measurements, and the other where they did not. Each disagreement was examined in detail in an attempt to establish the reason for the prediction being in error, and two broad classes emerged comprising errors due to visual editing and those due to the tolerances of the system. The results of this analysis are given in Table 1, where the number of places where differences existed is expressed in each case as a percentage of the total number measured.

The main purpose in testing the high-power transmitter sites is to establish where the relay stations will be required. A second analysis was carried out to determine how the predictions for relay stations compared with the relay requirements determined by testing. For this, as well as the next analysis, the predicted results were taken as they were obtained, not excluding errors due to visual editing. Of twenty-nine relay sites recommended as necessary in the site test reports, twenty-two were shown to be necessary in the predictions. The predictions showed the remaining seven as served. They also suggested that relays would be required at three other sites found in the tests to be adequately served.

A third analysis examined for each service area the net difference in population coverage represented by the differences given in Table 1,

TABLE 1

FIG. NO.	TRANSMITTER SITE	NUMBER OF TOWNS MEASURED	PERCENTAGE OF TOWNS WHERE A DIFFERENCE EXISTED	PERCENTAGE OF TOWNS WHERE THE DIFFERENCES WERE DUE TO EDITING ERRORS	PERCENTAGE OF TOWNS WHERE THE DIFFERENCES WERE DUE TO THE TOLERANCES OF THE SYSTEM
3	Bristol	45	11·1	4·4	6·7
4	Divis	134	23·1	15·7	7·4
5	Pontop Pike	176	26·7	11·3* 6·3	9·1
6	Sutton Coldfield	125	40·8	31·2	9·6
7	Tacolneston	269	27·1	13·0	14·1
8	Wenvoe	157	20·4	13·4	7·0

* The towns and villages represented by this figure were edited out, not in error, but because they were situated in the service area of the N. Yorks transmitter.

and expressed this difference as a percentage of the estimated total population coverage for the area. The estimated coverage was taken to be seventy-five per cent of the population served by the Band I transmitter for the same area, as unfortunately the total population that will be served by each of the high-power u.h.f. transmitters considered is not at present available. The errors expressed as these net percentage differences in population coverage are given in Table 2.

TABLE 2

Net Percentage Difference in Population Coverage

Bristol*	-
Divis	3·8%
Pontop Pike	2·5%
Sutton Coldfield	11·0%
Tacolneston	7·0%
Wenvoe	3·7%

4. CONCLUSIONS

An attempt was made to predict objectively the limit of an u.h.f. broadcasting service area by photographing a relief map suitably illuminated. A method was developed for relating the densities in the photograph to field strength, but due to the high level of light scattered from the white surface of the map, objectivity could not be maintained throughout the prediction process in the experiment as performed. The errors in the experimental procedure proved greater than had originally been expected.

* No Band I transmitter exists for the Bristol site, and no estimate of total coverage could therefore be made. The net difference in the populations of the towns where the photo-predictions disagreed with the site tests is 15,300. As the total population that will be served by the Bristol transmitter will certainly exceed one million, the percentage error is seen to be small.

Examination of these errors has shown that a large proportion of them resulted from imperfect visual editing of the photographs to remove the effects of scattered light. It is in principle possible to make the system entirely objective by reducing the reflexion coefficient of the map surface to a sufficiently low figure. The method cannot, however, be considered at present as a fully acceptable substitute for measurements made in the field. It can, nevertheless, give an estimate of the service area in a much shorter time than would be required for actual measurement.

The emphasis in u.h.f. planning in the BBC has now turned to deciding the service areas of relay stations, areas which are geographically much smaller than those of the main stations. The photo-prediction technique is not useful in such cases because the relief maps available are of too small a scale.

It is not therefore proposed to pursue the technique further but it was thought worthwhile to describe briefly the work done.

5. REFERENCES

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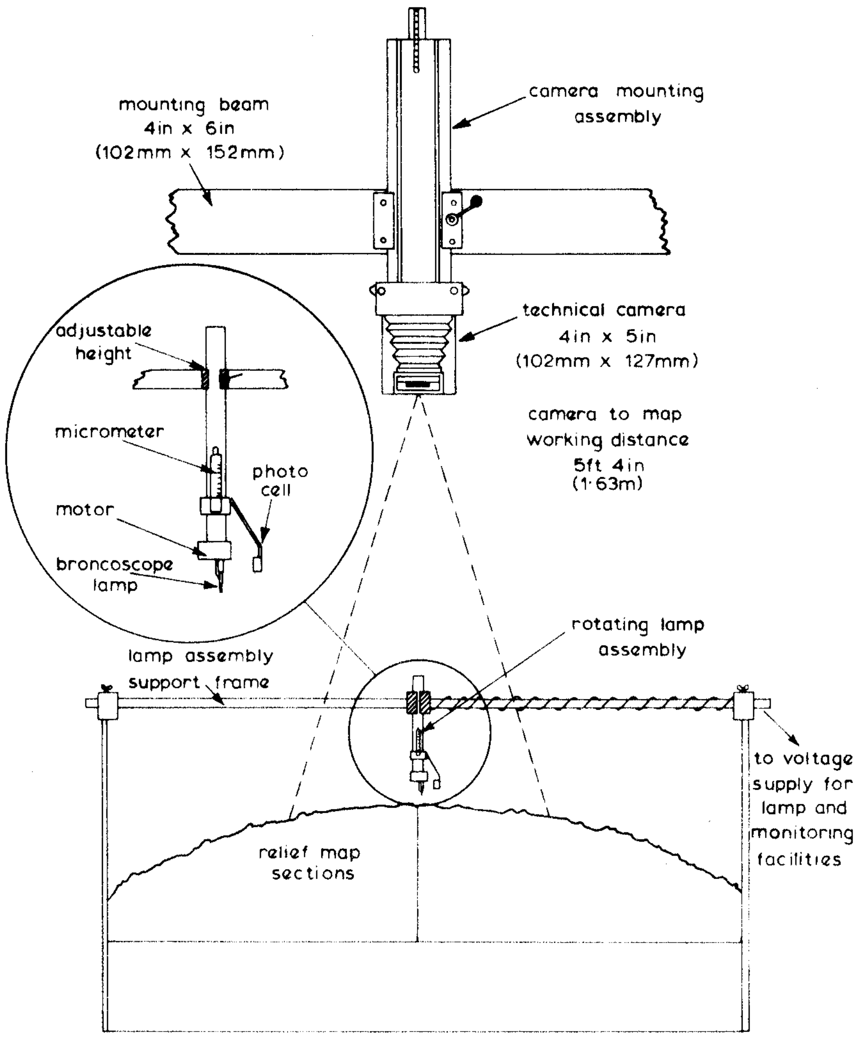


Fig. 1 - Layout of the experiment

The lamp could be placed over any point on the map with its axis normal to the surface. Its height was variable by a course and fine adjustment, and it was rotated during photographic exposure to smooth out the irregularities in the illumination it provided. Its intensity was monitored continuously during long exposures with the aid of a photocell, and maintained constant by adjusting the driving voltage manually.

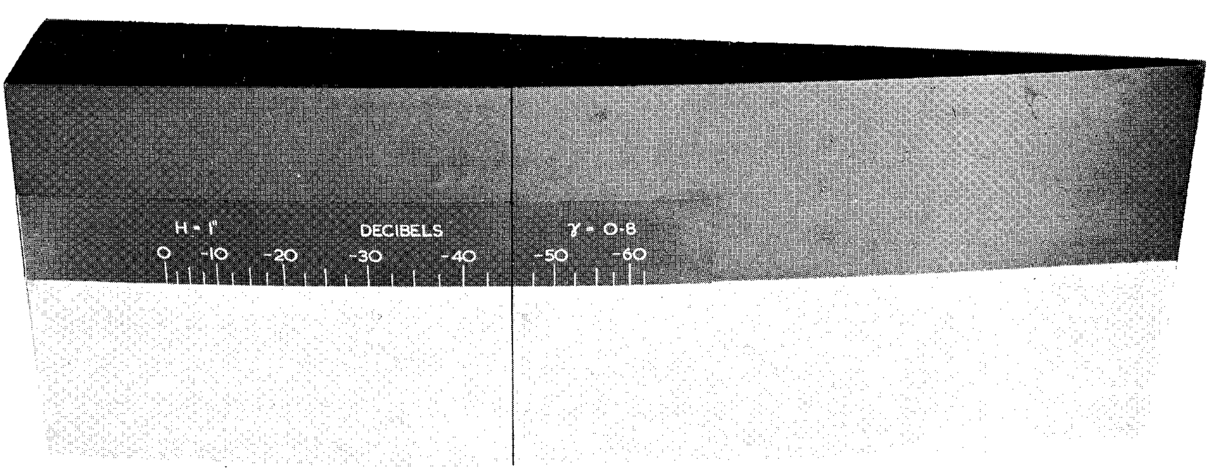
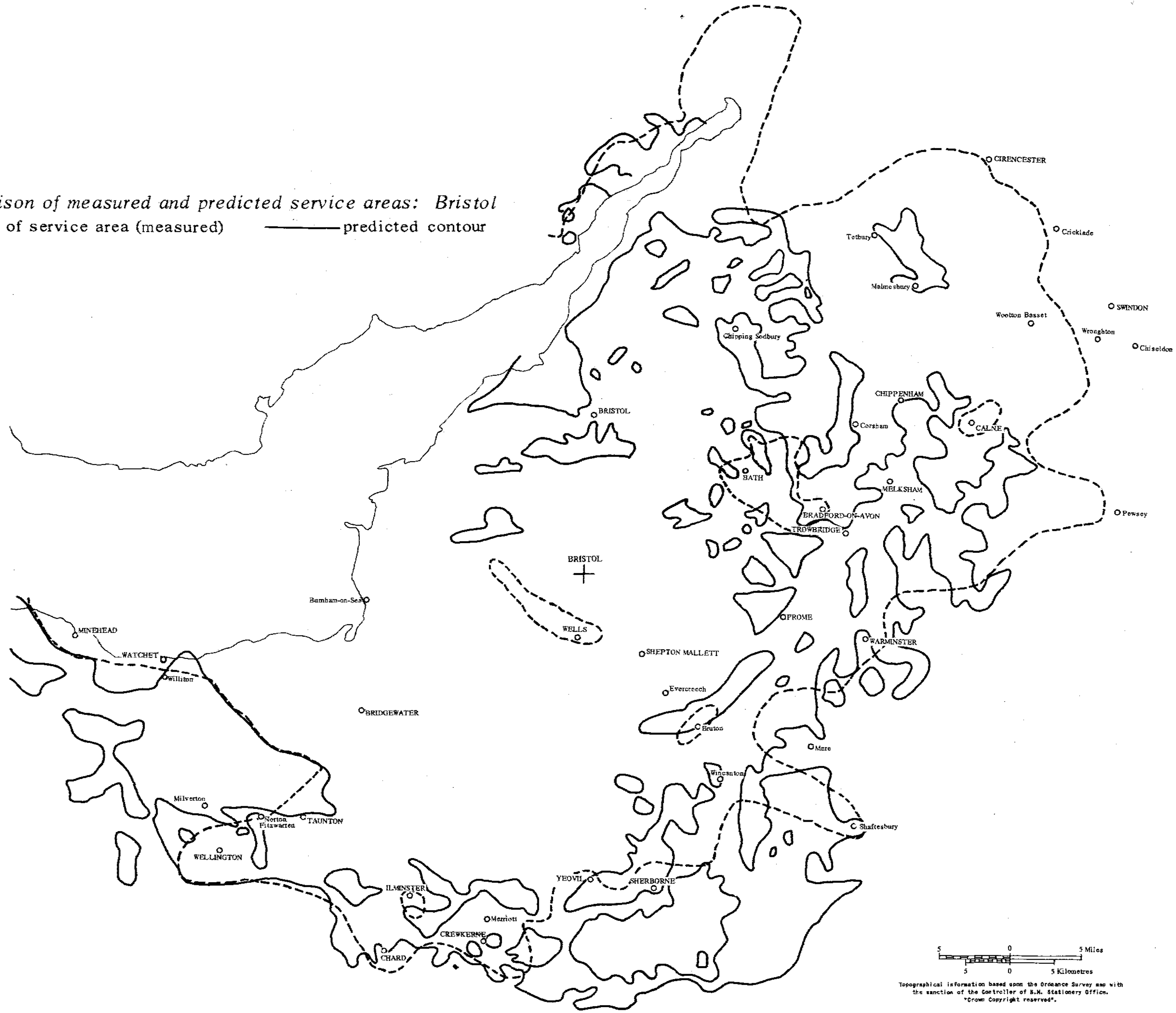


Fig. 2 - Calibration standard

Fig. 3 - Comparison of measured and predicted service areas: Bristol

-------Boundary of service area (measured) ———— predicted contour



Topographical information based upon the Ordnance Survey map with the sanction of the Controller of H.M. Stationery Office.

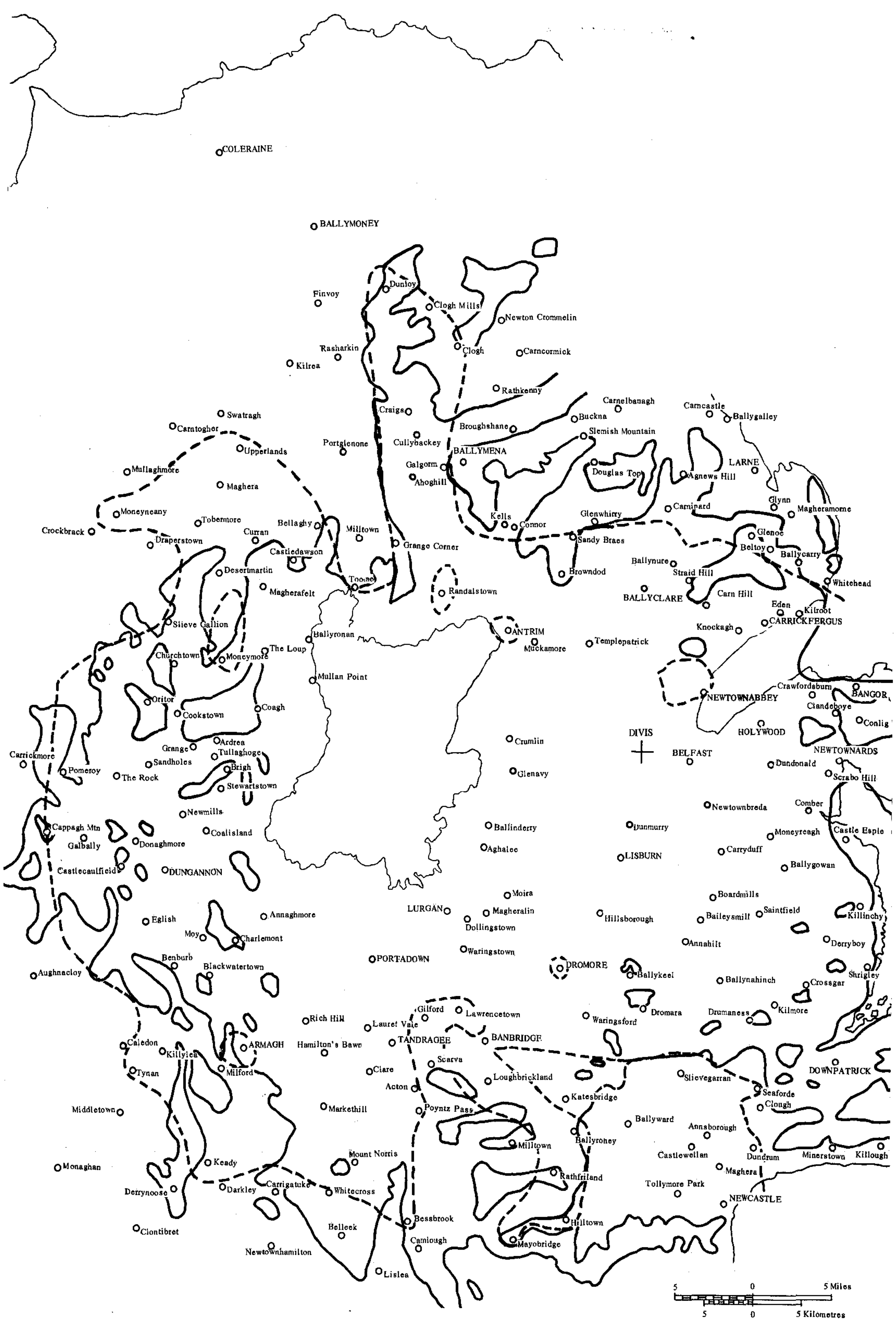


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Fig. 4 - Comparison of measured and predicted service areas: Divis

------- Boundary of service area (measured) ——— predicted contour

Fig. 5 - Comparison of measured and predicted service areas: Pontop Pike

------- Boundary of service area (measured) ——— predicted contour

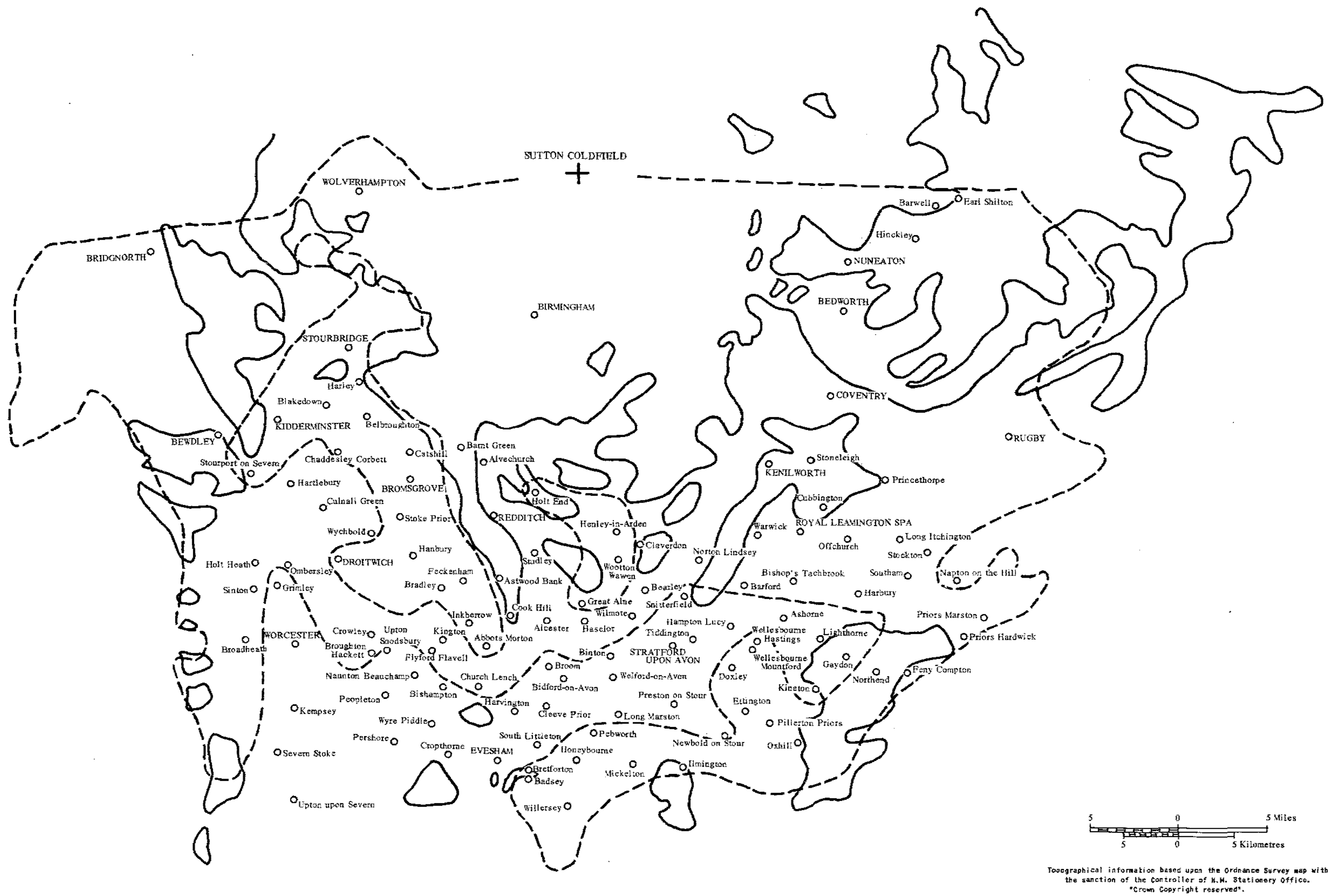

Fig. 6 - Comparison of measured and predicted service areas: Sutton Coldfield

-------- Boundary of service area (measured) ———— predicted contour

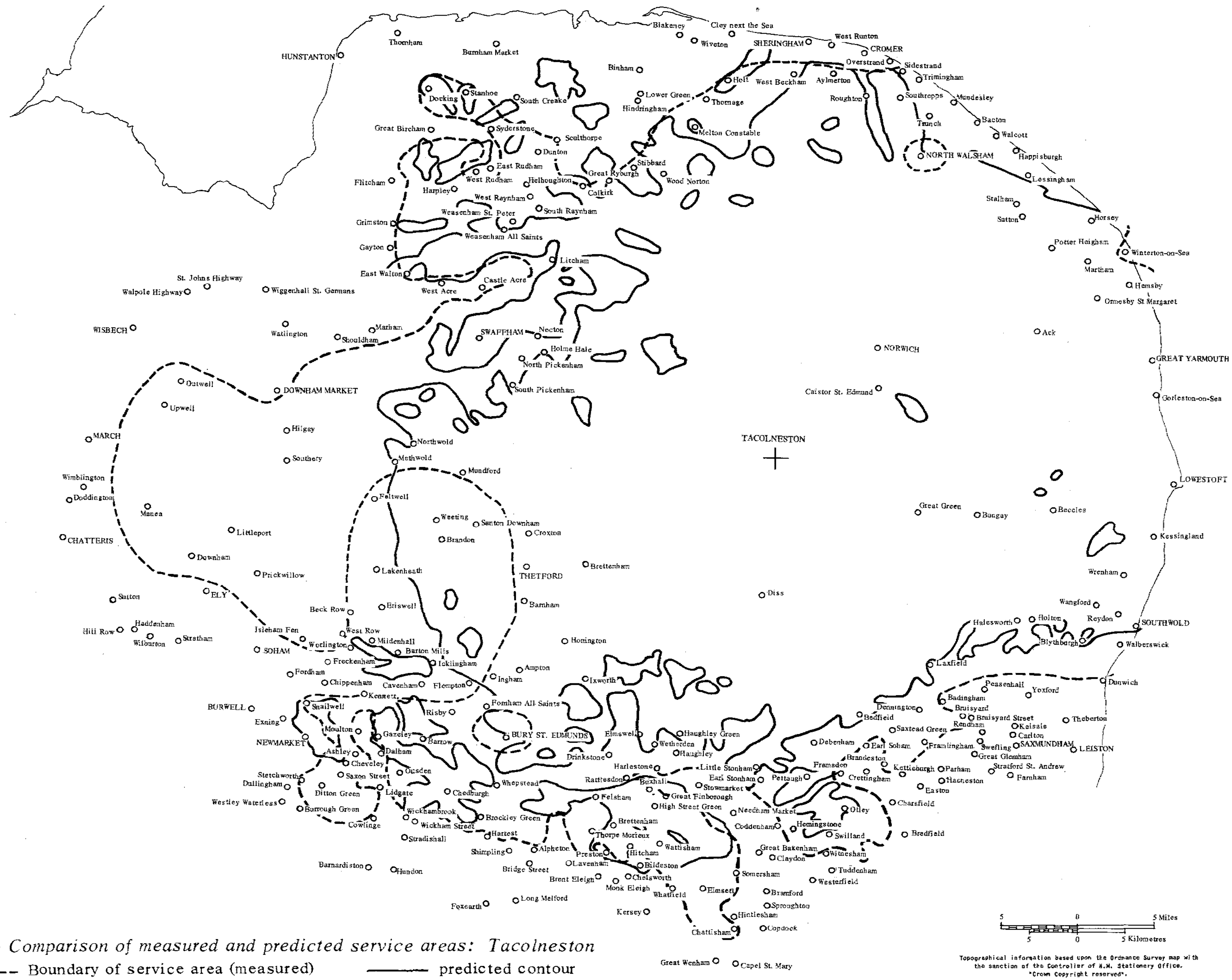

Fig. 7 - Comparison of measured and predicted service areas: Tacolneston

------ Boundary of service area (measured) ——— predicted contour

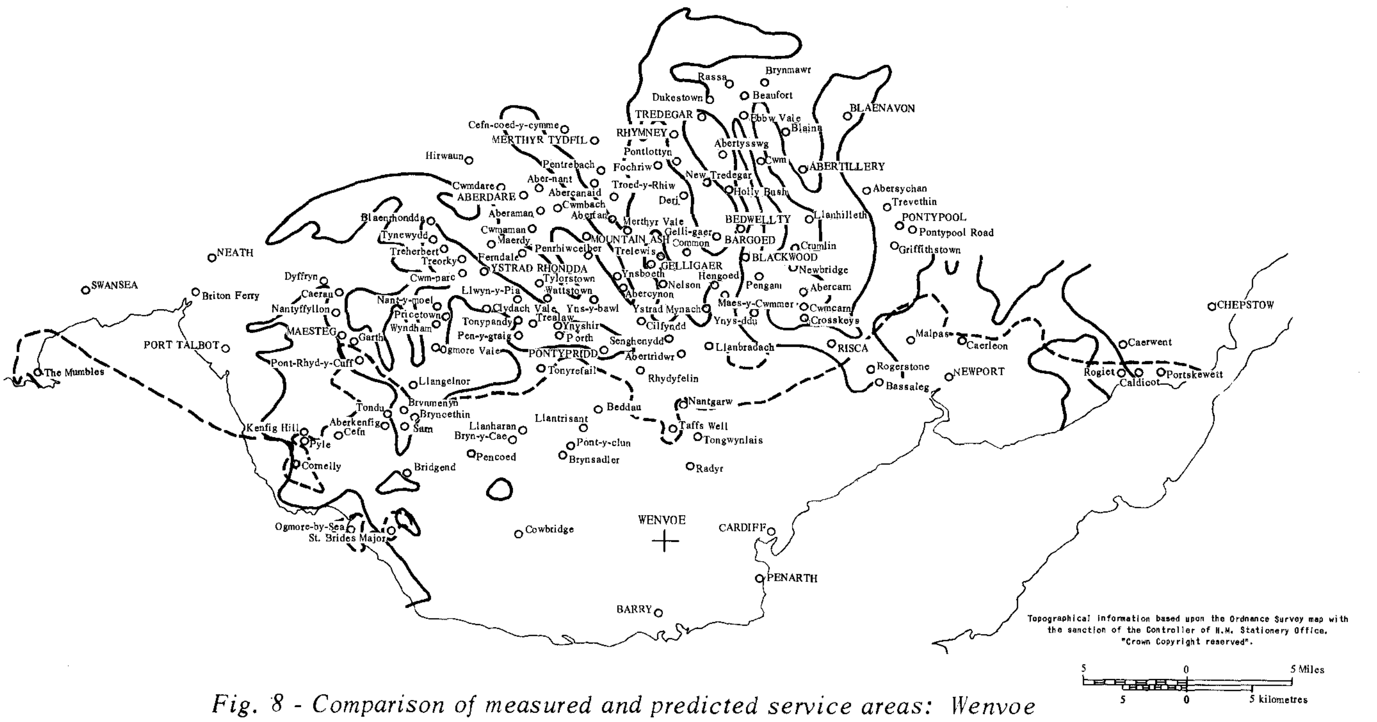

Fig. 8 - Comparison of measured and predicted service areas: Wenvoe

------ Boundary of service area (measured) ——— predicted contour

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